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17 November 1966

MEMORANDUM FOR THE RECORD

SUBJECT : Status of U-2R Engine - Propulsion System Planning

1. The following information is presented as a status review of engine and propulsion system aspects of U-2R planning. Most of the information presented herein was reviewed by the author with [redacted] of LAC on 17 and 19 October and [redacted] of Pratt & Whitney on 19 October. Some of this information has also been updated by recent phone conversations. 25X1

25X1

2. Engine/Aircraft Accessory Equipment and Fluid Systems:

a. The engine fuel/aircraft hydraulic oil cooler will be installed in the engine fuel system where the fuel totalizer valve is now located (i.e., between the main fuel control and the burner section fuel manifold) and the fuel totalizer valve will become part of the aircraft fuel system. Use of this fuel/hydraulic oil cooler may require an increase in allowable maximum fuel temperature to the engine. This limit as now fixed by Pratt & Whitney is 225°F maximum fuel temperature, as measured at the engine fuel manifold. LAC feels that increasing this allowable maximum to 250°F should not present any problem to the engine since the mil spec. coker test for this fuel* requires heating the fuel to 400°F. This will probably have to be verified by Pratt & Whitney. Recent experience in the OXCART program has indicated that established coker tests may not be the final criteria for determining possible precipitation of deposits from fuels at high temperatures. The 250°F temperature of the fuel from the fuel/hydraulic oil cooler should, according to LAC, occur only in the event of a CSD failure at altitude early in a mission while fuel is still relatively warm and if the throttle is brought back to minimum fuel flow.

*MIL-F-25524A

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A CSD failure increases hydraulic oil temperature because the pressure sensing pump will add additional energy to the hydraulic fluid to drive the hydraulic motors which power the emergency alternators if this system is finally used.

b. The currently planned arrangement for installation of accessories on the N_2 gear box does not call for any gear drive speed changes over the speeds currently used on J75-P-13B engines. The location of accessories on various N_2 gear box pads is planned as follows:

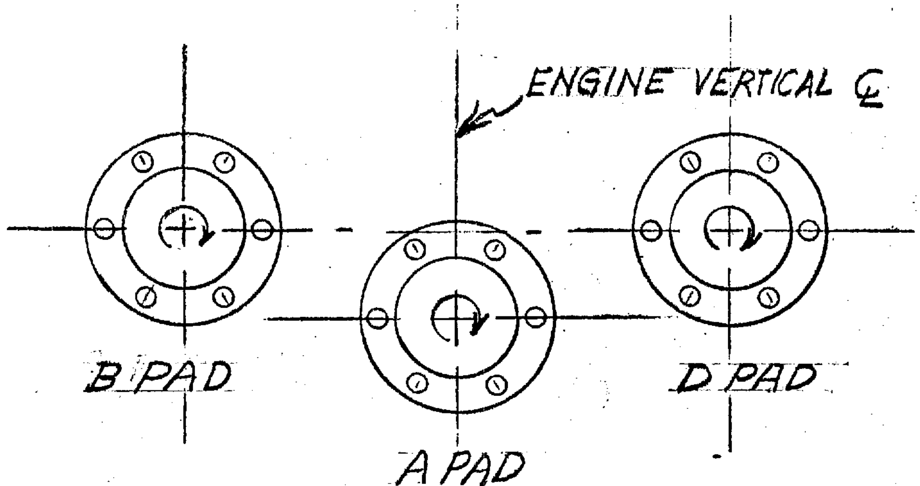
(1) The engine starter will be located in its normal position on the A pad.

(2) The Constant speed drive/alternator will be on the B pad.

(3) The D.C. generator will be on the D pad.

(4) The various pads on the front of the N_2 gear box are designated in the following sketch.

N_2 ROTOR GEAR BOX



VIEW LOOKING AFT

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The hydraulic pump will be located on the E pad which is the single "nose" pad on the N_1 gear box. Some objections have been expressed in the past by the engine contractor with regard to locating the hydraulic pump on the nose gear box due to the fact that possible leakage of hydraulic oil into the engine inlet may cause compressor contamination which could deteriorate high altitude performance. LAC indicates, however, that with proper sealing of the inlet duct fairing over the hydraulic pump at the engine face I.D. there should be no means for hydraulic fluid to enter the engine in the event of hydraulic pump leakage. The hydraulic fluid lines to and from the hydraulic pump would pass inside the flow splitter section of the inlet and not through the inlet airflow duct.

Speed changes of the N_2 gear box output shafts at the various pads will not be changed from the speeds currently provided. The D.C. generator speed increaser, lubricated by engine oil, currently in use will be retained and a speed increaser gear box will be required for the CSD. The CSD speed increaser unit will be lubricated by the CSD self contained oil system which is independent of both the engine oil and aircraft hydraulic oil. The speed ratio requirement to be provided by this speed increaser is still being reviewed by Sundstrand and will be determined by the maximum allowable RPM for the CSD/alternator unit based on stress limitations of this unit and the minimum allowable RPM based on alternator voltage and frequency limitations. Maximum N_2 will most likely occur at max power (665°C EGT) on a hot day during climb at about 5000 ft. Minimum N_2 will occur during idle descent conditions at low indicated air speeds. One consideration for a stand-by power electrical power generating system would be an alternator driven by hydraulic fluid motors. This system will take over when the CSD driven alternator falls off the line at low engine RPM (N_2).

However, such a system may not provide adequate electrical power under windmilling conditions in the event of a flameout especially at high altitude. Pratt & Whitney is currently estimating windmilling low and high rotor RPM's as a function of power extraction and air speed for LAC's evaluation.

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Some further questions regarding N_2 gear box accessory pad limitations still remain to be resolved. The current J75-P-13 and -13B engine installation manuals specify a type XII-K AND 20002 pad which supposedly only provides for a overhung moment of 350 in-lbs. LAC is now interested in changing both the B and D pads to a type XII-E AND 20002 which will provide for an overhung moment of 625 in-pounds. The D.C. generator and speed increaser have an overhung moment of 830 in-lbs. But this is identical to the current design which is supported on what is specified as a 350 in-lb. pad. If it is total gear box moment that is of primary concern to Pratt & Whitney, then the LAC suggested change to two 625 inch pound pads will provide for a total overhung moment from the front of the N_2 gear box of 1250 inch pounds in addition to the current and planned starter pad. A total allowable moment of 1250 inch pounds minus 830 for the D.C. generator will leave 420 inch pounds allowed for the CSD/alternator unit. This will no doubt result in the requirement for additional support of the CSD/ alternator unit from the C flange of the engine compressor case. This mounting arrangement would have to be flexible enough to allow for thermal expansions of the gear box relative to the compressor case. Some of these overhung moment problems result from the decision not to make speed (RPM) changes to the current B and D pad arrangements for engine interchangeability considerations (U-2C and U-2R). P&W is now taking the approach that LAC must first establish their accessory moment and load requirements and then they will evaluate them for engine compatibility. If, however, P&W can ascertain that enough strength margin has been designed into the the N_2 gear box housing, only a "paper" change to the engine manuals may be required.

c. Ram air/oil coolers will be provided for engine oil and CSD oil. This will be a new design plate-fin cooler and will consist of two oil coolers in one frame. The drag of this system has not been accounted for in performance estimates but it is assumed by LAC that improved propulsive efficiency of the planned exhaust ejector which has also not been included in performance estimates will more than compensate for the air/oil cooler drag. LAC is guaranteeing a maximum engine oil temperature from the air/oil cooler of 250°F. The CSD oil temperature limit from the air/oil cooler will be approximately the same.

d. Another engine fuel temperature limitation in addition to the temperature limitation at the engine fuel manifold previously mentioned, is a limit of 165°F to the main fuel control set by Pratt & Whitney for fuel control stability considerations. Since the engine fuel pump is, of course, located upstream of the fuel control and adds a considerable ΔT to the fuel, the 165°F limitation on fuel temperature to the control sets the maximum allowable fuel temp of the fuel at the aircraft sump tank discharge. An analysis of fuel pump ΔT (which is a function of pump speed, therefore N_2, and fuel flow) shows primarily a rapid increase in fuel pump ΔT with decreasing fuel flow on a climb profile. This combined with an analysis of flight test data recording sump tank discharge temperature with flight time taken on article 349 in the spring and summer of 1965, sets maximum allowable sump tank discharge temperature at 110°F at takeoff. This temperature limit might present problems if an aircraft were fueled and allowed to set in the sun in a hot climate before flight.

3. Engine Performance

Installed engine performance curves (Thrust specific fuel consumption versus installed net thrust) have been recomputed by LAC at altitudes of 60,000, 65,000 and 70,000 feet. These curves show generally higher TSFC values, primarily at part power on the 60,000 and 65,000 ft. curves and at all power levels on the 70,000 ft. curve compared to the curves presented earlier for the same altitudes in LAC report SP-973 of 12 April 1966. The revised LAC curves are, however, in generally good agreement with those computed by PSD/D/R&D and presented in D/R&D Performance Report [redacted] The relatively minor differences between these latest LAC and D/R&D installed engine performance curves can be attributed to recently revised LAC values of installed engine performance losses. A review of the revised engine installation losses is presented below. 25X1A

a. Inlet recovery

[redacted] 25X1D

[redacted]

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[redacted]

25X1D

It was stated that wind tunnel tests with a tufted inlet show no indications of separation on external duct lip even at angles of attack up to 12°. It is planned to instrument an inlet in the flight test program and utilize a swing rake probe for inflight measurement of thrust.

b. Tailpipe Pressure Loss

Tailpipe pressure losses $\frac{P_{T7}-P_{T8}}{P_{T7}}$ are held constant at a value of .015.

c. High Pressure Compressor Airbleed.

The latest high compressor bleed airflow requirements at various altitudes are as follows:

[redacted]

25X1D

d. Horse-power Extraction

N_1 Spool - 15 Horsepower

N_2 Spool - 26 Horsepower

A tentative set of installed fuel flow and installed net thrust curves computed by LAC are available for all altitudes.

SIGNED

[redacted]

25X1A

PSD/D/R&D

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[redacted]

25X1

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25X1A

PSD/R&D/OS[redacted]gp (17 November 1966)
Distribution:
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